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DEVELOPMENT OF HPM NONPROPAGATION WALLS: TEST RESULTS AND DYNA3D PREDICTIONS OF ACCEPTOR RESPONSE

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ABSTRACT

Numerical predictions of the response of critical acceptors subjected to an explosion in an adjacent HPM storage cell are conducted using the three-dimensional Lagrangian finite element hydrocode DYNA3D. The acceptors include M107-155 mm projectiles, MK82 bombs, MK107 torpedoes and MK55 mines. For each acceptor type, the numerical model includes up to six acceptors located in a cell per the applicable High Performance Magazine (HPM) stowage plan.

Non-propagation wall initial conditions (predicted in a separate analysis using the hydrocode AUTODYN-2D) are applied and the acceptor explosive fill pressure-time histories and case deformations are calculated. Peak explosive fill pressures and case deformations are compared to threshold allowables and results from a full scale HPM nonpropagation wall test. Predicted responses are shown for full scale prototype tests scheduled for early FY95.

INTRODUCTION

Background

The Naval Facility Engineering Service Center is developing a new ordnance storage magazine, the High Performance Magazine (HPM). The performance goals of the HPM are to reduce encumbered land and to improve operational efficiency. The concept uses cell walls and aisle walls to prevent propagation of an explosion to adjacent cells. This significantly reduces the Maximum Credible Event (MCE), reducing encumbered land by more than 80% and reducing safe standoff range by more than 50%. The non-propagation dividing walls also allow storage of noncompatible ordnance in the same magazine. A new handling system, which utilizing an overhead bridge crane and universal stradle lift, provides improved operational efficiency, selectability, and versatility.

The most important factor in the improved explosives safety performance of the HPM is the reduction in the MCE. For example, the explosive storage capacity of the Type II HPM is

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295,000 pounds net explosive weight (NEW) but the MCE is no more than 30,000 pounds NEW in the storage areas and 55,000 pounds NEW in the shipping and receiving area. Inhabited building distance (IBD) is reduced from 3345 ft. to 1330 ft. (60% reduction in safe distance and 84% reduction in encumbered land area).

NFESC has shown that the HPM concept is feasible based on analytical modeling and test results (small and full scale). In FY93 NFESC conducted two explosive tests of full scale storage cells which demonstrated that the non-propagation storage cell walls will prevent sympathetic detonation to MK82 bombs and M107-155mm projectiles. The non-propagation walls were designed limit the peak pressure and deformation of the acceptor weapons (M107-155 mm projectiles and MK 82 Bombs). The explosive fill pressures and case crushing were calculated using the Lagrangian finite element code DYNA3D [1].

In FY94-96, NFESC will conduct additional full-scale explosive tests to certify explosives safety of the HPM prototype design. These tests will be designed to certify compliance with explosives safety regulations for each maximum credible hazard scenario in the HPM.

Design of the non-propagation walls requires calculation of the response of the acceptors to impact from the wall. DYNA3D is being used to calculate this design response. The calculated response is compared to acceptable SD threshold criteria.

Purpose

This paper outlines the procedures being used to calculate the response of the acceptor to design MCE loads and to compare test and analytical results. Full scale test data is presented and compared to DYNA3D predictions. The predicted response of selected acceptor weapons in the HPM Certification Test #1, scheduled for early FY95 is also presented.

The objectives are to : (1) demonstrate the effectiveness of the HPM non-propagation walls to prevent sympathetic detonation, and (2) to verify DYNA3D numerical models for predicting acceptor deformation and internal fill pressures.

Scope

Small and one-third scale wall tests were conducted in FY92 & FY93 to study the mitigation effects of candidate wall designs on sympathetic detonation. The wall design parameter effectiveness for mitigating acceptor loads and sympathetic detonation were evaluated with test data and AUTODYN [2] prediction of rigid body acceptor response. The small scale and one-third scale test results are given in references 3 and 4.

Full scale wall tests were conducted in FY 94 to demonstrate the effectiveness of proposed prototype wall concepts. Rigid body acceptor response data (acceleration and velocity) from instrumented acceptors are compared to AUTODYN predictions in reference 3. This paper presents predicted thick skin acceptor deformation and internal fill pressures and compares them to test data and to design criteria for preventing sympathetic detonation. Predicted thick

skin acceptor responses for a full scale magazine certification test, scheduled for FY96, are also shown. The thick skin acceptors considered are M107-155mm projectiles and MK82 bombs. Preliminary analyses are also reported for two thin-skin acceptors: MK55 mines and MK107 torpedoes.

NUMERICAL SIMULATIONS

Setup

The standard setup for the numerical simulations is shown in Figure 1. The aisle wall is comprised of a 72-inch sand core held between two 18-inch sections of CBC (Chemically Bonded Ceramic) [5]. Blast analyses using AUTODYN predicted a wall velocity of 160 m/s, which was used as initial condition in the DYNA3D calculations. A first set of predictions without back wall is presented and compared to results from a FY94 full scale wall test.

A second set of predictions is carried out for the FY96 full scale HPM magazine test. In this case the back wall is included, and 3 to 5 acceptors are simulated between the aisle wall and the back wall. The latter is represented by an 18-inch CBC section assumed perfectly restrained on the back side. The tributary wall area impacting the acceptors was determined by the stack spacing horizontally, and the acceptor spacing vertically. The perimeter of the tributary area was restrained laterally to simulate symmetrical loading of several acceptor stacks. This is a conservative assumption, as it increases the wall confinement and the pressures in the acceptors. By symmetry, only the half of the wall and the acceptors was modeled.

CBC

CBC's are designed with both high strength and high porosity, and can absorb substantial amounts of energy via pore collapse. In the analyses, most of the deformation is taken by the CBC sections, allowing the pressures to remain low.

TEST RESULTS

M107-155mm projectiles

A total of 42 projectiles were stacked near the wall and subjected to lateral loading. The projectiles were placed in four rows, the first one being closest to the wall. The major projectiles diameter, D, was reduced by $\Delta D/D < 0$ along the load direction, whereas it increased in the direction perpendicular to the load. These relative deformations are shown in Figure 2. It is observed that the largest average relative deformation is almost 15% in compression for the second row of acceptors and at about mid-height.

MK82 bombs

Only 6 bombs were placed laterally and deformations were measured in only 5 of them. These deformations are indicated in Figure 3. It is observed that maximum relative deformations in compression of about 12% occurred in two bombs.

NUMERICAL PREDICTIONS

M107-155mm projectiles

Prior to the test a numerical prediction was carried out with 3 projectiles and no back wall. Predicted lateral deformation histories are shown in Figure 4a for all three acceptors (1 being closest to the aisle wall) at mid-height. It is shown that projectile number 2 was predicted to reach relative deformations of about 18%, sliglthly higher than the observed test average. The pressure in projectile 2 reached about 2 Kbars (Figure 4b), well below the threshold of 4 Kbars (0.75 UST).

Predictions for the full scale HPM magazine test were carried out for 3 and 5 projectiles. A close-up detail of the 3 and 5 projectile setups is shown in Figure 5. Figure 6 shows the pressure and Figure 7 the deformation time histories. Pressures were monitored at several locations in the fill and only the worse ones are reported. Peaks pressures reached about 2 Kbar. Deformations were obtained as the relative displacement of diametrically opposed points at various locations on the acceptors, but values at mid-height are reported. The first and last acceptors showed less deformation (and pressure) than the interior ones. The maximum relative deformations predicted are just below the case rupture threshold of 25%. These predictions may also be slightly conservative.

MK82 bombs

Predictions of the full scale wall test were carried out using 3 bombs and no back wall. Calculated relative deformations at the center of the three bombs are shown in Figure 8. Bomb 2 (second row) shows the largest deformation, which reaches 21%. This is a conservative prediction since the maximum observed test value was 12%. However, the test data was limited, and the analyses only consider the worst case of 3 perfectly aligned acceptors which remain aligned after the explosion. Pressures were less than 1.5 Kbar.

MK55 mines

Preliminary analyses indicate that pressures will be kept below 3 Kbar, but relative deformations may exceed 35%. These large relative deformations would result in case craking.

MK107 torpedos

Preliminary analyses using acceptors without cannisters indicate that pressures would remain

below 3.2 Kbar, but deformations may exceed 30%. This would result in cracking of the aluminum case. Case cracking has been observed in separate flyer plate tests.

CONCLUSIONS

The full scale wall tests have demonstrated the effectiveness of the HPM nonpropagation walls to prevent sympathetic detonation for thick skin munitions. The nonpropagation wall concept is a significant improvement over previous technology, with a significant reduction in permanent deformation in the acceptors (see Figure 9 for comparison of MK82 bomb deformations). Observed permanent relative deformations measured at the largest diameter $\Delta D/D$ were less than 15%, i.e. below the 25% threshold. DYNA3D analyses did conservatively predict the permanent deformations and indicated maximum fill pressures of about 2 Kbar, i.e. below the allowed thresholds and consistent with the test results.

DYNA3D predictions of the full scale HPM magazine test indicate that fill pressures will remain low but relative case deformations may increase close to the threshold.

For thin skin munitions, only preliminary results were obtained indicating possible case cracking although still at low fill pressures.

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Figure 1. Test Setup.

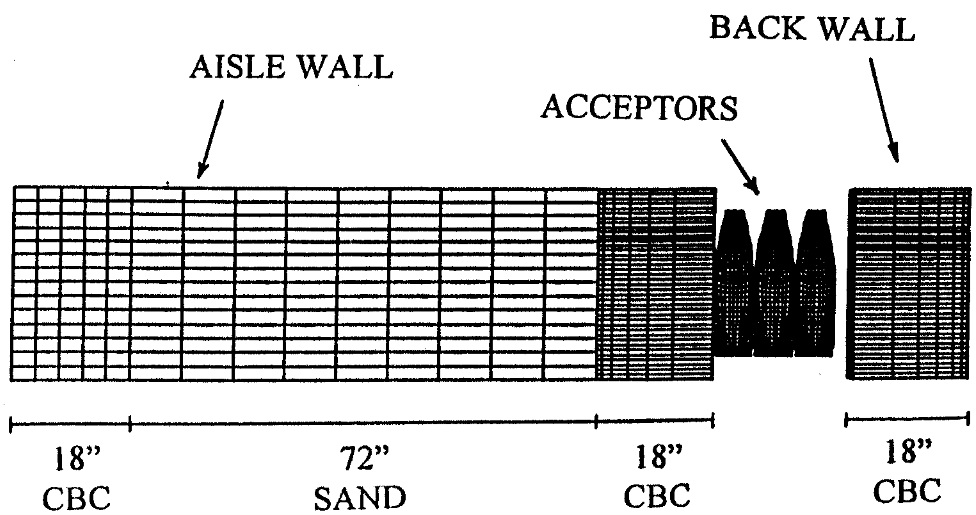


Fig 1. Test setup.

Figure 2. Test Results. Projectiles.

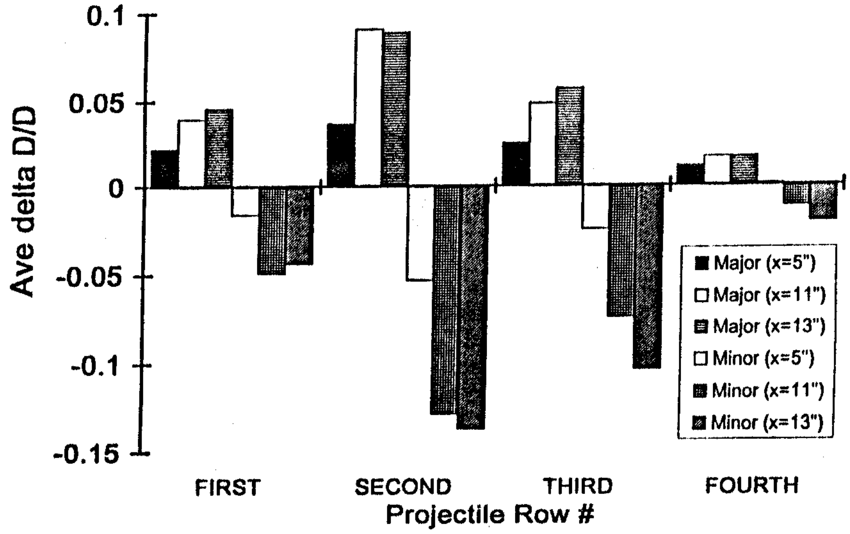


Fig 2. Test results,
Projectiles.

Figure 3. Test Results. MK82 bombs.

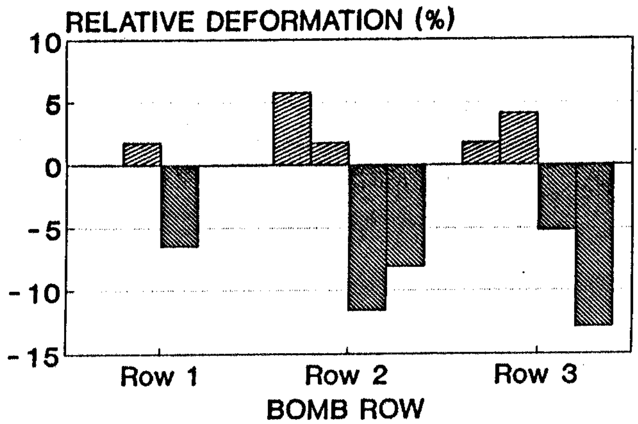


Fig 3. Test results,
MK82 bombs.

Figure 4. Full Scale Wall Test Predictions, 3 Projectiles.

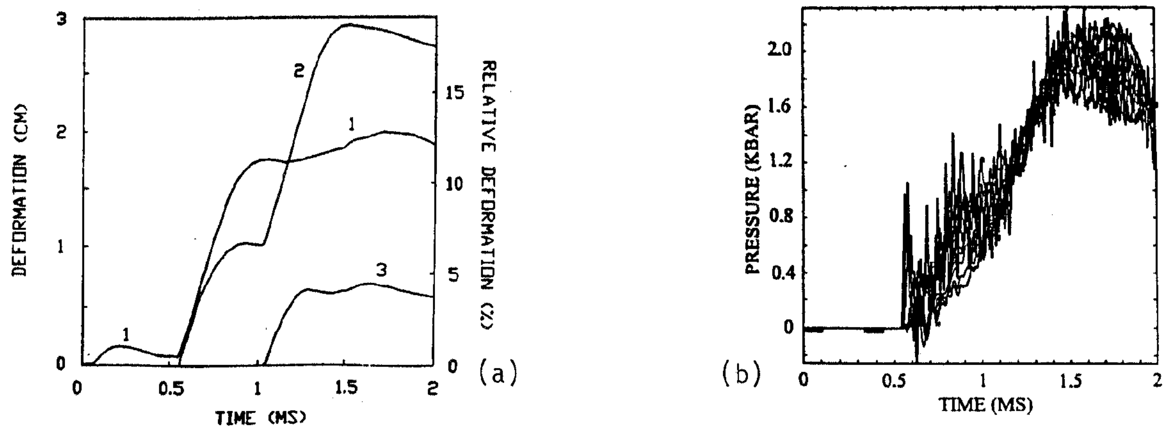
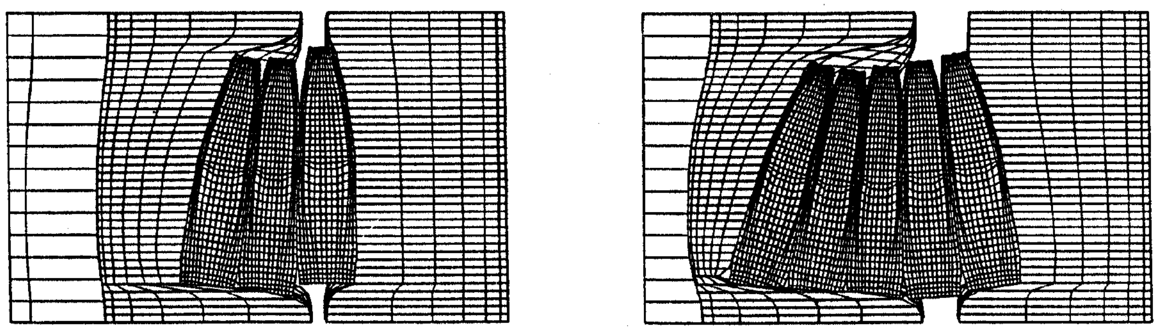


Fig 4. Full scale wall test predictions, 3 projectiles.

Figure 5. HPM Certification Test Models, 3 and 5 Projectiles.



(a) (b)

Fig 5. HPM certification test models, 3 and 5 projectiles.

Figure 6. Full Scale HPM Certification Test. Pressures in Second Projectile.

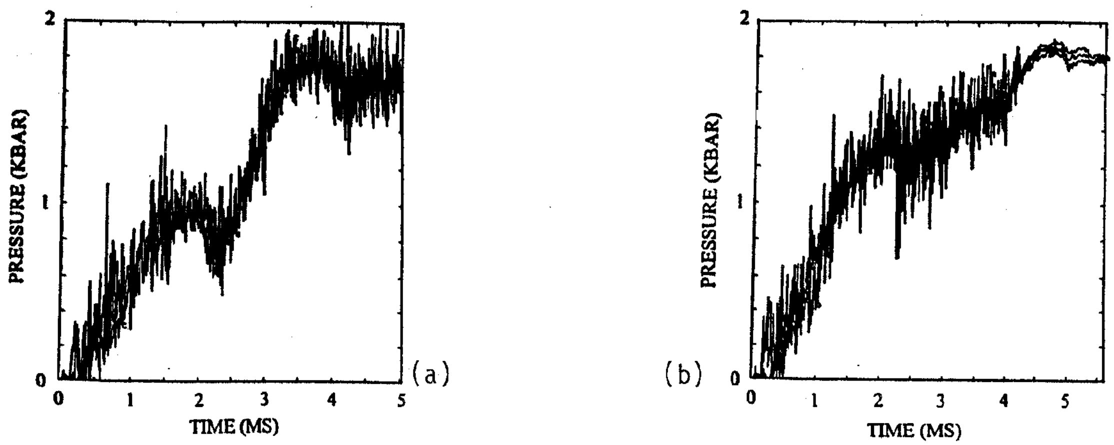


Fig 6. Full scale HPM certification test.
Pressures in second projectile.

Figure 7. Full Scale HPM Certification Test.
Case Deformation Predictions, M107-155mm.

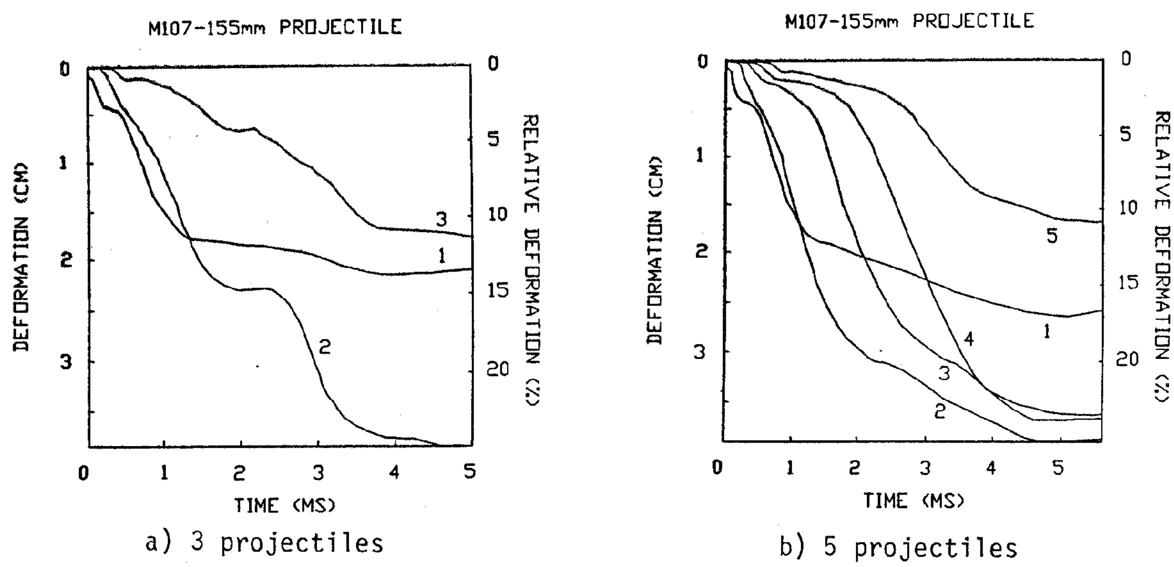


Fig 7. Full scale HPM certification test.
Case deformation predictions, M107-155mm.

Figure 8. Full Scale Wall Test.
Case Deformation Predictions, MK82.

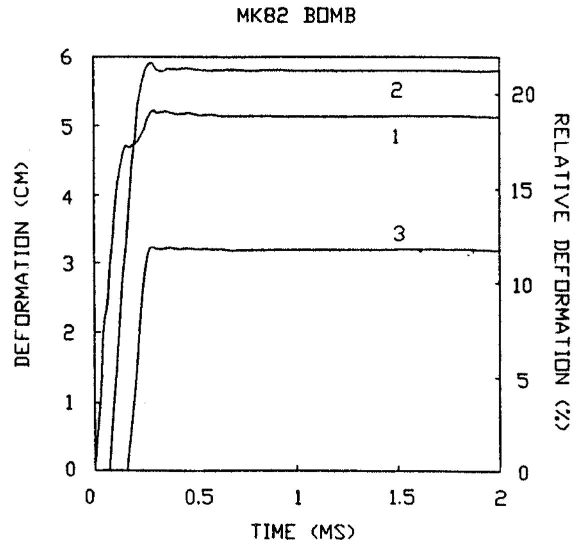


Fig 8. Full scale wall test. Case deformation predictions, MK82.

Figure 9. Test Results, MK82 Bomb.